Predictors of conversion to thoracotomy for video-assisted thoracoscopic lobectomy: A retrospective analysis and the influence of computed tomography–based calcification assessment

Pamela Samson, MD,[a] Julian Guitron, MD,[a,b] Michael F. Reed, MD,[a] Dennis J. Hanseman, PhD,[c,d] and Sandra L. Starnes, MD[a,b]

Objective: Conversion to an open thoracotomy during video-assisted thoracoscopic surgery lobectomy is reported to occur in up to 23% of cases and can be associated with increased morbidity. We developed a preoperative computed tomography calcification score based on anatomic location and extent of calcifications to evaluate the ability to predict video-assisted thoracoscopic surgery conversion.

Methods: Patients undergoing planned video-assisted thoracoscopic surgery lobectomy between 2003 and 2009 were identified. Baseline demographics, comorbidities, operative data, and postoperative outcomes were reviewed. Preoperative chest computed tomography scans were examined by an attending thoracic surgeon. Calcifications were scored from 0 (none) to 6 (major hilar calcifications at the resection bronchus). Preoperative patient and tumor characteristics and the calcification score were analyzed for their ability to predict conversion. We then compared outcomes among patients undergoing video-assisted thoracoscopic surgery, converted video-assisted thoracoscopic surgery, and planned open thoracotomy.

Results: Of the 193 patients undergoing planned video-assisted thoracoscopic surgery lobectomy, 148 (77%) had a completed video-assisted thoracoscopic surgery lobectomy, and 45 (23%) underwent conversion to thoracotomy. The calcification score was found to independently predict video-assisted thoracoscopic surgery conversion. Patients who were converted to a thoracotomy had significantly higher 30-day mortality, more atrial arrhythmias, increased blood loss, longer operative time, and increased length of stay compared with those who underwent completed video-assisted thoracoscopic surgery lobectomy and longer length of stay compared with those undergoing planned open lobectomy.

Conclusions: Calcification score based on the location and degree of calcifications can predict the increased likelihood of video-assisted thoracoscopic surgery conversion. This scoring system could be one element used to choose the approach for a lobectomy, especially during a surgeon's learning curve. (J Thorac Cardiovasc Surg 2013;145:1512-8)

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The use of video-assisted thoracoscopic surgery (VATS) for the surgical management of lung cancer has become increasingly more common; however, only a minority of lobectomies are performed thoracoscopically.[1] One of the reasons that could explain why this approach has not gained more widespread use is the concern for intraoperative complications. Conversion to a thoracotomy is reported to occur in up to 23% of cases.[2-4] The ability to predict which patients are more likely to require conversion to thoracotomy has not been thoroughly addressed to date. The goal of this study was to explore the influence of patient-related factors on VATS conversion, specifically, the influence on granulomatous disease. In our experience, VATS conversion is frequently related to hilar calcifications that result from the high incidence of histoplasmosis in the Ohio and Mississippi River valleys. Granulomatous inflammation of the hilar lymph nodes can make thoracoscopic dissection of the hilum technically challenging and increases the risk of vascular injury. To test the hypothesis that granulomatous inflammation increases VATS conversion, we developed a preoperative computed tomography (CT) calcification score based on anatomic location and extent of calcifications. The primary objective of this study was to determine whether this calcification score and other preoperative factors, such as obesity, predict an increased rate of conversion. The secondary objective was to determine the consequences of VATS conversion on postoperative outcomes compared with completed VATS lobectomy and planned open lobectomy.

From the Division of Thoracic Surgery,[a] Department of Surgery, University of Cincinnati College of Medicine, Cincinnati, Ohio; Cincinnati Veterans Affairs Medical Center,[b] Cincinnati, Ohio; Division of Trauma and Critical Care,[c] Department of Surgery, University of Cincinnati College of Medicine, Cincinnati, Ohio; and Center for Sustainment of Trauma and Readiness Skills,[d] US Air Force.
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Address for reprints: Sandra L. Starnes, MD, University of Cincinnati College of Medicine, 231 Albert B. Sabin Way, PO Box 670558, Cincinnati, OH 45267 (E-mail: sandra.starnes@uc.edu).
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Abbreviations and Acronyms

CT = computed tomography
VATS = video-assisted thoracoscopic surgery

PATIENTS AND METHODS

Patients

All patients undergoing an elective lobectomy, either VATS or open, at the University Hospital and the Veterans Affairs Medical Center, both in Cincinnati, Ohio, between 2003 and 2009 were identified. Patients were excluded if they underwent resection other than lobectomy or they did not have a preoperative chest CT available for analysis. Data extracted included baseline demographics, comorbidities, preoperative evaluation, operative data, and postoperative morbidity and mortality. Reasons for VATS conversion and planned open thoracotomy were obtained from the operative notes. The protocol was approved by the University of Cincinnati Institutional Review Board with a waiver for informed consent.

Calcification Score

For each patient, the preoperative chest CT was examined by 1 of 2 attending thoracic surgeons who were blinded to the patient identification and surgical outcome (S.S. and J.G.). The images were scored according to the classification system shown in Table 1.

TABLE 1. Calcification scoring system

Calcification finding	Score
No calcifications	0
Extrathoracic (liver and spleen)	1
Intraparenchymal pulmonary	2
Mediastinal or contralateral hilar	3
Ipsilateral hilar, not adjacent to the resection bronchus	4
Minor calcifications at the resection bronchus (<5 mm)	5
Major calcifications at the resection bronchus (≥5 mm)	6

Operative Technique

All procedures were performed by 1 of 3 dedicated general thoracic surgeons. All surgeons used similar criteria for attempted VATS lobectomy. VATS lobectomy was attempted in clinical stage I and II lung cancer. Contraindications to VATS lobectomy include bulky hilar lymph nodes, neoadjuvant chemoradiation, mediastinal lymph node disease, tumors greater than 6 cm in size, need for resection of chest wall or mediastinal structures, and need for sleeve lobectomy or bilobectomy. All patients underwent general anesthesia using a double-lumen endotracheal tube for lung isolation. VATS lobectomy was performed in the lateral decubitus position using a 4-cm utility incision at the anterior axillary line at the fourth or fifth intercostal space, a 12-mm port in the seventh or eighth intercostal space at the posterior axillary line, a 12-mm port in the sixth intercostal space at the anterior axillary line, and a 12-mm port in the sixth intercostal space in the posterior ausculatory triangle. No rib retractors were used. The individual vascular and bronchial structures were divided using an endoscopic stapling device, and mediastinal lymphadenectomy was performed in all cases. A single chest tube was inserted at the lower port site at the end of the procedure. Conversion to thoracotomy was at the discretion of the attending surgeon and was typically done by extending the utility incision to a standard axillary thoracotomy. Patients were generally extubated in the operating room and transferred to the surgical intensive care unit.

Statistical Analysis

Statistical analysis was performed using SAS, version 9.2 (SAS Institute, Inc, Cary, NC). Patient characteristics and surgical outcomes of the completed VATS and converted VATS groups were compared using chi-square tests, Student *t* tests, or Wilcoxon rank-sum tests, as appropriate. For predictors of VATS conversion to open thoracotomy, a univariate logistic regression analysis was applied for possible variables that may influence conversion, including patient demographics, lobe of resection, body mass index, pulmonary function, tumor size, reoperation, calcification score, and time of surgery (generating odds ratios with 95% confidence intervals). A multivariable logistic analysis was then performed using variables with a univariate *P* value less than .15. Surgical outcomes, including mortality, morbidity, length of surgery, length of stay, estimated blood loss, and duration of chest tube drainage. were described using counts and percentages, as well as medians and ranges. We also compared outcomes between patients converted to VATS and patients undergoing planned open lobectomy from the same time period to determine whether VATS conversion to thoracotomy is associated with worse outcomes compared with planned thoracotomy. By comparing the converted VATS and planned thoracotomy groups, we used univariate and multivariate linear and logistic regression analyses to determine factors associated with longer length of stay and combined mortality/morbidity, respectively. Combined mortality and morbidity included 30-day mortality, air leak more than 7 days, reintubation, postoperative pneumonia, postoperative acute respiratory distress syndrome, postoperative tracheostomy, and postoperative atrial fibrillation.

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RESULTS

Predictors of Conversion of Lobectomy by Video-Assisted Thoracoscopic Surgery Lobectomy to Open Thoracotomy

From 2003 to 2009, 193 patients underwent planned VATS lobectomy. A total of 148 (77%) of these patients had a complete VATS lobectomy, and 45 patients (23%) underwent conversion to thoracotomy. Patient characteristics of the completed and converted VATS groups are shown in Table 2. Patient characteristics were similar between the groups except for the calcification score. Patients in the converted VATS group trended toward a higher likelihood of being current smokers and having a lower percentage of predicted forced expiratory volume in 1 second than the completed VATS group, although this did not reach statistical significance. A difference in the assigned calcification score was demonstrated between the completed VATS and converted VATS groups (2.2 vs 2.9, respectively, $P = .04$). The reasons for conversion are shown in Table 3.

The results of the univariate and multivariate analyses for predictors of conversion are shown in Table 4. For the time of surgery, we divided all attempted VATS lobectomy cases into quartiles since the time of the first VATS lobectomy to explore the relationship of a possible learning curve to conversion. Calcification score as a continuous variable was the only factor associated with a higher conversion rate in the multivariable model. Each 1-unit increase in calcification score increased the odds of conversion. To increase the clinical utility of the calcification score, we then analyzed the results by group (0-2, 3-4, 5-6). Patients in group 0-2 (no evidence of calcification along the bronchial tree) had the lowest rate of conversion (17%), patients in group 3-4 (calcifications along the bronchial tree away from the lobe

TABLE 2. Patient characteristics: Converted video-assisted thoracoscopic surgery and completed video-assisted thoracoscopic surgery lobectomy

Variable	Converted VATS (n = 45)	Completed VATS (n = 148)	P value
Female gender	17 (38%)	65 (44%)	.47
Race			
Black	7 (16%)	42 (28%)	.19
Caucasian	37 (82%)	101 (68%)	
Other	1 (2%)	5 (3%)	
Coronary artery disease	10 (22%)	39 (26%)	.57
Hypertension	31 (69%)	91 (62%)	.39
Chronic renal insufficiency	1 (2%)	1 (1%)	.42
Diabetes	10 (22%)	25 (17%)	.42
History of smoking	43 (96%)	137 (93%)	.74
Current smoker	25 (58%)	57 (42%)	.06
Location lobe			
LLL	7 (16%)	17 (12%)	.43
LUL	10 (22%)	27 (18%)	
RLL	6 (13%)	31 (21%)	
RML	1 (2%)	12 (8%)	
RUL	21 (47%)	61 (41%)	
Ipsilateral reoperation	2 (4%)	5 (4%)	.66
Malignant disease	44 (98%)	147 (99%)	.41
Pretreatment stage			
IA	25 (58%)	108 (73%)	.12
IB	12 (28%)	32 (22%)	
IIA	1 (2%)	2 (1%)	
IIB	3 (7%)	2 (1%)	
IIIA	1 (2%)	0 (0%)	
IIIB	1 (2%)	2 (1%)	
IV	0 (0%)	2 (1%)	
	Mean (SD)	**Mean (SD)**	***P* value**
Age	64.1 (11.7)	63.0 (10.0)	.53
Body mass index	27.1 (8.2)	27.3 (6.5)	.86
Pack-y smoked	59.4 (35.6)	51.5 (36.5)	.22
FEV_1 % predicted	77.5 (15.4)	83.2 (21.2)	.06
DLCO % predicted	65.7 (21.3)	70.8 (21.6)	.20
Tumor size (cm)	2.78 (1.56)	2.39 (1.24)	.13
Calcification score	2.91 (2.09)	2.18 (2.04)	**.04**

VATS, Video-assisted thoracoscopic surgery; *LLL*, left lower lobe; *LUL*, left upper lobe; *RLL*, right lower lobe; *RML*, right middle lobe; *RUL*, right upper lobe; *SD*, standard deviation; *FEV_1*, forced expiratory volume in 1 second; *DLCO*, diffusion capacity of carbon monoxide.

of resection) had an intermediate rate of conversion (25%), and patients in group 5-6 (calcifications at the bronchus of resection) had the highest rate of conversion (37%) ($P = .03$).

Outcomes of Converted Video-Assisted Thoracoscopic Surgery Versus Completed Video-Assisted Thoracoscopic Surgery

We then examined the perioperative morbidity and mortality between the completed VATS and converted VATS groups (Table 5). Patients who underwent conversion had significantly higher 30-day mortality ($P = .01$). Of the 4 deaths in the converted VATS group, 1 was due to ventricular fibrillation on postoperative day 2, 1 was due to acute respiratory distress syndrome that occurred after the transection and reanastomosis of an unrecognized common pulmonary vein early in our experience, 1 was due to acute respiratory distress syndrome of unknown cause, and 1 was due to an unexplained death at home that occurred at 30 days postprocedure. Morbidities were similar except for more frequent atrial arrhythmias ($P = .04$) in the converted VATS group. Length of surgery, intraoperative estimated blood loss, duration of chest tube placement, and hospital stay were all greater in patients requiring VATS conversion.

TABLE 3. Reasons for video-assisted thoracoscopic surgery conversion as detailed in operative reports

Reasons for converted VATS (n = 45)	
Hilar calcifications/granulomatous inflammation	16/45 (36%)
Adhesions (hilar or pleural)	15/45 (33%)
Bleeding (pulmonary artery or pulmonary vein)	10/45 (22%)
Body habitus	2/45 (4%)
Other (chest wall invasion, limited pulmonary collapse with bronchial blocker)	2/45 (4%)

VATS, Video-assisted thoracoscopic surgery.

TABLE 4. Predictors of video-assisted thoracoscopic surgery conversion to open thoracotomy

Variable	Univariate analysis OR (95% CI)	Univariate analysis P value	Multivariable analysis OR (95% CI)	Multivariable analysis P value
Location (UH vs VAMC)	0.69 (0.34-1.42)	.31		
Female gender	0.78 (0.39-1.54)	.47		
Race				
Black vs Caucasian	0.46 (0.19-1.10)	.20		
Other vs Caucasian	0.55 (0.06-4.83)			
Lobe of resection				
LLL vs RUL	1.20 (0.44-3.29)	.48		
LUL vs RUL	1.08 (0.45-2.59)			
RLL vs RUL	0.56 (0.21-1.54)			
RML vs RUL	0.24 (0.03-1.98)			
Ipsilateral reoperation	1.33 (0.25-7.10)	.74		
Age	1.01 (0.98-1.04)	.53		
Body mass index	0.99 (0.95-1.05)	.87		
FEV_1 % predicted	0.99 (0.97-1.00)	.12		
DLCO % predicted	0.99 (0.97-1.00)	.19		
Tumor size (cm)	1.20 (0.99-1.45)	.07		
Calcification score (continuous)	**1.19 (1.01-1.40)**	.04	**1.23 (1.03-1.47)**	**.03**
Time since first case (quartiles)	1.26 (0.90-1.76)	.18		

OR, Odds ratio; *CI*, confidence interval; *UH*, University Hospital; *VAMC*, Veterans Affairs Medical Center; *LLL*, left lower lobe; *RUL*, right upper lobe; *LUL*, left upper lobe; *RLL*, right lower lobe; *RML*, right middle lobe; *FEV_1*, forced expiratory volume in 1 second; *DLCO*, diffusion capacity of carbon monoxide.

TABLE 5. Comparison of postoperative outcomes between patients undergoing converted video-assisted thoracoscopic surgery and completed video-assisted thoracoscopic surgery lobectomy

Variable	Converted VATS (n = 45)	Completed VATS (n = 148)	*P* value
30-d mortality	4 (9%)	1 (1%)	**.01**
Air leak > 7 d	5 (11%)	10 (7%)	.35
Reintubation	3 (7%)	3 (2%)	.14
Postoperative pneumonia	4 (9%)	8 (5%)	.48
Postoperative ARDS	1 (2%)	2 (1%)	.55
Postoperative tracheostomy	3 (7%)	2 (1%)	.08
Atrial arrhythmia	10 (22%)	14 (9%)	**.04**
	Median (25th, 75th percentile)	**Median (25th, 75th percentile)**	***P* value**
Length of stay (d)	6 (5-9.5)	4 (3-6)	**<.01**
Length of surgery (min)	252 (210-335)	211 (183.5-243.5)	**<.01**
Chest tube (d)	4 (3-6)	3 (2-4)	**<.01**
EBL (mL)	325 (200-600)	150 (100-250)	**<.01**

VATS, Video-assisted thoracoscopic surgery; *ARDS*, acute respiratory distress syndrome; *EBL*, estimated blood loss.

Outcomes Between Converted Video-Assisted Thoracoscopic Surgery Lobectomy and Planned Open Lobectomy

We further compared patients who underwent a converted VATS to patients scheduled for a planned thoracotomy to determine whether the differences in outcome between patients who underwent converted VATS and completed VATS were simply the result of a thoracotomy. Reasons for planned thoracotomy for lobectomy in the 91 patients from the same time period are listed in Table 6. Table 7 shows the patient characteristics for the converted VATS and planned thoracotomy groups. They were similar except for a higher rate of hypertension in the converted VATS group and higher stage and larger tumor size in the planned thoracotomy group. Comparisons of perioperative outcomes between the converted VATS group and the planned thoracotomy group are shown in Table 8. Atrial arrhythmia was more frequent in the patients converted to VATS. The planned thoracotomy group had a shorter median length of surgery, chest tube duration, and estimated blood loss. The results of univariate and multivariate analyses for length of stay and combined mortality and morbidity are shown in Tables 9 and 10. For length of stay, a converted VATS procedure and preoperative percent predicted diffusing capacity for carbon monoxide were the only independent predictors of longer length of stay (Table 9).

TABLE 6. Reasons for planned thoracotomy

Reasons for planned thoracotomy (n = 91)	
Approach not conducive to VATS (en bloc chest wall resection, planned muscle flap, sleeve resection)	22/91 (24%)
Status post-neoadjuvant chemotherapy or radiation therapy	16/91 (18%)
Size (4.5-8.7 cm range)	11/91 (12%)
Hilar calcifications documented at preoperative conference	11/91 (12%)
Reoperation	6/91 (7%)
Central hilar location of tumor	6/91 (7%)
Adhesions noted with wedge resection	5/91 (5%)
VATS not yet at VAMC during 2003	5/91 (4%)
Not specified	9/91 (10%)

VATS, Video-assisted thoracoscopic surgery; *VAMC*, Veterans Affairs Medical Center.

TABLE 7. Patient characteristics: Converted video-assisted thoracoscopic surgery and thoracotomy groups

Variable	Converted VATS (n = 45)	Thoracotomy (n = 91)	*P* value
Female gender	17 (38%)	20 (33%)	.58
Race			
Black	7 (16%)	16 (18%)	.07
Caucasian	37 (82%)	72 (79%)	
Other	1 (2%)	3 (3%)	
Coronary artery disease	10 (22%)	25 (27%)	.51
Hypertension	31 (69%)	44 (48%)	**.02**
Chronic renal insufficiency	1 (2%)	2 (2%)	1.00
Diabetes	10 (22%)	20 (22%)	.97
History of smoking	43 (96%)	78 (87%)	.14
Current smoker	25 (58%)	35 (44%)	.14
Location lobe			
LLL	7 (16%)	10 (11%)	.89
LUL	10 (22%)	26 (30%)	
RLL	6 (13%)	13 (15%)	
RML	1 (2%)	2 (2%)	
RUL	21 (47%)	37 (42%)	
Ipsilateral reoperation	2 (4%)	7 (8%)	.72
Malignant disease	44 (98%)	82 (100%)	.35
Pretreatment stage			
IA	25 (58%)	27 (31%)	**<.01**
IB	12 (28%)	28 (33%)	
IIA	1 (2%)	3 (3%)	
IIB	3 (7%)	11 (13%)	
IIIA	1 (2%)	9 (10%)	
IIIB	1 (2%)	4 (5%)	
IV	0 (0%)	4 (5%)	
	Mean (SD)	**Mean (SD)**	***P* value**
Age	64.1 (11.7)	61.8 (12.9)	.32
Body mass index	27.1 (8.2)	27.0 (6.4)	.97
Pack-y smoked	59.4 (35.6)	52.4 (30.1)	.32
FEV_1 % predicted	77.5 (15.4)	75.5 (21.1)	.54
DLCO % predicted	65.7 (21.3)	62.4 (20.8)	.42
Tumor size (cm)	2.78 (1.56)	3.92 (2.28)	**.004**
Calcification score*	2.91 (2.09)	2.81 (2.27)	.74

VATS, Video-assisted thoracoscopic surgery; *LLL*, left lower lobe; *LUL*, left upper lobe; *RLL*, right lower lobe; *RML*, right middle lobe; *RUL*, right upper lobe; *SD*, standard deviation; *FEV_1*, forced expiratory volume in 1 second; *DLCO*, diffusion capacity of carbon monoxide. *Treated as a continuous variable.

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TABLE 8. Comparison of postoperative outcomes between patients undergoing converted video-assisted thoracoscopic surgery and planned open thoracotomy

Variable	Converted VATS (n = 45)	Thoracotomy (n = 91)	P value
30-d mortality	4 (9%)	2 (2%)	.10
Air leak > 7 d	5 (11%)	6 (7%)	.51
Reintubation	3 (7%)	4 (4%)	.69
Postoperative pneumonia	4 (9%)	3 (3%)	.22
Postoperative ARDS	1 (2%)	0 (0%)	.33
Postoperative tracheostomy	3 (7%)	1 (1%)	.11
Atrial arrhythmia	10 (22%)	9 (10%)	**.054**
	Median (25th, 75th percentile)	**Median (25th, 75th percentile)**	**P value**
Length of stay (d)	6 (4-9.5)	5 (4-7)	.07
Length of surgery (min)	252 (210-335)	215 (168-270)	**.02**
Chest tube (d)	4 (3-6)	3 (2-5)	**.02**
EBL (ml)	325 (200-600)	200 (125-387.5)	**.02**

VATS, Video-assisted thoracoscopic surgery; *ARDS*, acute respiratory distress syndrome; *EBL*, estimated blood loss.

Pack-years smoked was the only factor associated with combined mortality and morbidity in multivariate analysis (Table 10).

TABLE 9. Univariate and multivariate analyses for predictors of length of stay between converted video-assisted thoracoscopic surgery and planned thoracotomy groups

	Univariate		Multivariate	
	Estimate (SE)	P value	Estimate (SE)	P value
Gender: female	–0.12 (0.11)	.25		
Race: non-Caucasian	0.30 (0.13)	**.02**		
Coronary artery disease	0.02 (0.12)	.87		
Hypertension	–0.04 (0.10)	.71		
Chronic renal insufficiency	0.19 (0.35)	.58		
Diabetes	–0.02 (0.12)	.84		
History of smoking	0.27 (0.17)	.12		
Current smoker	0.21 (0.11)	.052		
Ipsilateral reoperation	–0.11 (0.20)	.58		
Benign disease	–0.39 (0.58)	.50		
Age	0.001 (0.004)	.80		
Body mass index	–0.02 (0.01)	**.02**		
FEV_1 % predicted	–0.004 (0.003)	.13		
Pack-y	–0.002 (0.002)	.29		
DLCO % predicted	–0.004 (0.003)	.11	–0.005 (0.002)	.056
Tumor size (cm)	0.004 (0.024)	.85		
Calcification score	–0.011 (0.013)	.63		
Approach: converted VATS	0.25 (0.11)	**.002**	0.39 (0.11)	**.001**

Factors with a $P \leq .15$ in univariate analysis were subjected to multivariate analysis. Dependent variable was log-transformed to compensate for extreme right skew. *SE*, Standard error; *FEV_1*, forced expiratory volume in 1 second; *DLCO*, diffusion capacity in the lung for carbon monoxide; *VATS*, video-assisted thoracoscopic surgery.

TABLE 10. Univariate and multivariate analyses for predictors of combined morbidity and mortality between converted video-assisted thoracoscopic surgery and planned thoracotomy groups

	Univariate		Multivariate	
	Odds ratio	P value	Odds ratio	P value
Gender: female	1.04 (0.47-2.29)	.93		
Race: non-Caucasian	0.72 (0.27-1.96)	.52		
Coronary artery disease	1.92 (0.84-4.38)	.12		
Hypertension	1.49 (0.69-3.22)	.32		
Chronic renal insufficiency	5.60 (0.49-63.69)	.16		
Diabetes	1.19 (0.49-2.91)	.69		
History of smoking	1.43 (0.38-5.45)	.60		
Current smoker	2.03 (0.90-4.56)	.09		
Ipsilateral reoperation	1.32 (0.31-5.59)	.70		
Benign disease	7.86 (0.08-753.04)	.38		
Age	0.99 (0.07-1.03)	.84		
Body mass index	0.97 (0.92-1.03)	.36		
Pack-y	1.02 (1.00-1.03)	**.024**	1.02 (1.00-1.03)	**.024**
FEV_1 % predicted	0.99 (0.97-1.01)	.28		
DLCO % predicted	0.99 (0.97-1.01)	.17		
Tumor size (cm)	0.92 (0.76-1.12)	.42		
Calcification score	1.06 (0.89-1.26)	.50		
Converted VATS	3.48 (1.58-7.67)	**.002**		

Factors with a $P \leq .15$ in univariate analysis were subjected to multivariate analysis. *FEV_1*, Forced expiratory volume in 1 second; *DLCO*, diffusion capacity in the lung for carbon monoxide; *VATS*, video-assisted thoracoscopic surgery.

DISCUSSION

VATS lobectomy was introduced in the 1990s and has subsequently been demonstrated to be safe and effective for the treatment of early-stage lung cancer.[5,6] It is associated with decreased morbidity and length of stay.[1] Despite the advantages, only approximately 30% of lobectomies registered in the Society of Thoracic Surgeons database are performed thoracoscopically.[1] One of the reasons that VATS lobectomy has not gained more widespread use may be the concern for intraoperative complications, especially during a surgeon's learning curve. This may discourage smaller centers from adopting VATS lobectomy.

We undertook the present study to determine whether preoperative factors could be used to determine the likelihood of conversion in VATS lobectomy and to determine what the impact of VATS conversion was on postoperative outcomes compared with completed VATS lobectomy and planned open lobectomy. If we could identify patient factors predicting the likelihood of conversion, this may prompt surgeons to select patients for an open approach, especially early in their learning curve. We were particularly interested in granulomatous nodal inflammation because this study was performed in an area of endemic histoplasmosis. In our practice, patients with extensive hilar calcifications (score of 6) are generally resected with a thoracotomy. However, we have observed that certain patients who do not have calcifications in the hilum of dissection nonetheless have extensive granulomatous inflammation in the lymph nodes around the hilum. This prompted us to develop a scoring system to determine whether the degree and location of calcifications can be used to predict the severity of inflammatory changes in the hilum.

In this analysis of 193 planned VATS lobectomies, higher calcification score predicted a higher conversion rate to thoracotomy. Patients with a calcification score of 2 or less had a 17% rate of conversion. These are ideal patients to undergo attempted VATS lobectomy, especially in a surgeon's learning period. Patients with evidence of calcification along the bronchial tree, but not along the hilum of resection (score of 3-4), have an intermediate rate of conversion (25%). Patients with calcifications involving the hilum of resection (score 5-6) have a 37% risk of conversion. These final 2 groups can undergo attempted VATS lobectomy, but perhaps this should not be attempted during the learning curve or by surgeons who are not as experienced with open pulmonary resection in these patients. To our surprise, other factors, such as the lobe resected and body mass index, were not predictive of conversion. We also demonstrated that when compared with completed VATS, converted VATS operations were significantly more likely to result in postoperative atrial fibrillation, increased length of stay, increased duration of chest tube drainage, longer surgery time, and increase in estimated blood loss. On comparison of converted VATS to planned open thoracotomy, VATS conversion was an independent predictor of longer length of stay, although combined mortality and morbidity were similar.

The conversion rate in our study is higher than in previous reports, likely for several reasons. First, we included the period of our initial learning curve in the analysis. We did this because the ability to preoperatively identify patients who are less likely to undergo successful VATS lobectomy may be even more important in a surgeon's learning period. Second, we work in an endemic area of histoplasmosis. Third, we included all patients who were planned to undergo VATS lobectomy, including those patients who were converted to a thoracotomy before hilar dissection was started because of pleural adhesions or difficult visualization on initial thoracoscopic assessment.

Few studies have specifically examined VATS conversions, especially predictors of conversion. Reasons for conversion can be divided grossly into 2 categories, emergency (due to vascular injury) or elective (due to a technically difficult dissection). Gazala and colleagues[7] analyzed their experience with VATS lobectomy and developed a classification system for reasons of conversion. They classified conversions into vascular injuries; anatomic reasons, such as adhesions, bulky, or sticky lymph nodes; and technical issues, such as stapler misfire or equipment failure. Their overall conversion rate was 13.5% with most conversions due to anatomy or lymph nodes. Forty-one percent of conversions were due to vascular injuries, although the details of these vascular injuries were not specified. Only 9% of conversions were due to bulky or sticky lymph nodes. Although their reported mortality was low, the length of stay was longer for patients requiring conversion to thoracotomy.

In another study examining unplanned conversion for VATS lobectomy by Park and colleagues,[8] 41% of conversions were due to hilar nodal anthracofibrosis and hilar adhesions. When the authors retrospectively reviewed the CT scans, hilar calcifications were seen in 71% of these patients. Conversion to thoracotomy was associated with increased operative time and length of stay.

To date, there are few studies evaluating the role of imaging studies in selecting the surgical approach for lobectomy, and those that do are limited to the size and location of the tumor. Mason and colleagues[9] evaluated the role of imaging studies in predicting complications associated with VATS and demonstrated that pleural thickening and calcifications on CT or chest x-ray predicted difficulties. However, this study included all VATS procedures with only a small number of lobectomies.

Several studies have examined the implications of unplanned conversion from VATS to thoracotomy. One study evaluated the outcomes in 26 patients who underwent a converted VATS procedure and compared them with the outcomes of 52 patients who underwent a planned thoracotomy. There were no significant differences between the groups in the perioperative (30-day) or long-term outcomes.[10] Sawada and colleagues[11] found that VATS conversion was associated with increased blood loss, perioperative complications, and length of surgery compared with completed VATS, which is similar to our data.

A limitation of our study is that 12.1% of the planned thoracotomies were selected for an open approach because of the density of hilar calcifications observed on preoperative chest CT. This group of patients selects out some of the patients who may have otherwise been converted to thoracotomy had the VATS approach been initially attempted. Therefore, this finding likely results in a more conservative relationship between calcification score and conversion rate that is already statistically significant without accounting for this groups. These 11 thoracotomies that were planned open on the basis of hilar calcifications were all assigned a calcification score of 6 by the thoracic surgeons who were blinded to the surgical outcome when evaluating the preoperative CT scans.

CONCLUSIONS

Large hilar calcifications from histoplasmosis lead to more challenging dissections that place the patient at higher risk for longer anesthesia times, increased blood loss, and increased likelihood of conversion to a thoracotomy. In auditing the reasons for converted VATS, hilar calcifications and granulomatous disease were frequent findings that resulted in a higher conversion rate compared with other centers. Our calcification scale is an attempt to provide an evidence-based system in the selection of the appropriate surgical approach for a lobectomy. This may be especially important in the early experience of surgeons performing VATS lobectomies, maximizing patient safety, and optimizing the surgeon's progressive exposure to more challenging cases as he or she moves along the learning curve.

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